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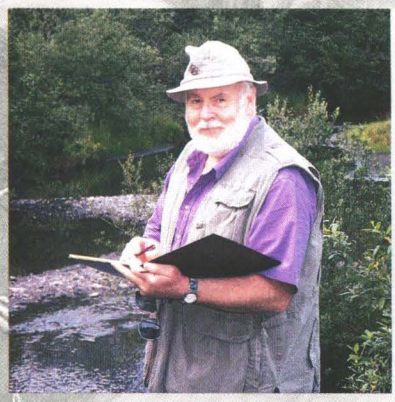
Forest Service Fish Habitat and Aquatic Ecosystem Research

Understanding and Managing Aquatic Ecosystems

Why Research–the Need
The Essential Resource–the National Forests and Grasslands
The Benefits–Conserving Aquatic Communities
What's Next–a Future for Fish



Scientific Understanding of Fish Communities and Aquatic Ecosystems

Making a Difference in Resource Management

Understanding–the Essential Element to Managing Wisely. With a sense of urgency, Forest Service scientists press hard for a greater understanding of the workings of natural aquatic ecosystems and better technologies and tools for ecosystem management. To deliver on the promise of managing wisely–managing for the long term–National Forest and Grassland managers continue to ask researchers the hard questions: What constitutes first-class care of aquatic ecosystems and how do we assess how well we are delivering that kind of care?

Aquatic Ecosystems on the National Forests and Grasslands–Rich, Extensive, and Significant. The streams and rivers, the estuaries, and the lakes, ponds, and reservoirs of the 191 million acres of National Forests and Grasslands are vital to the productivity and diversity of fish and other aquatic species in the United States. The Forest Service is responsible for the care of these aquatic ecosystems containing some of the most valuable fish species in the world.

A Broad Diversity of Fish, Mussels, Snails, Aquatic Insects–To Name a Few. A broad diversity of coldwater, warmwater, and anadromous fish and other aquatic species feed, grow, and reproduce in aquatic ecosystems on the National Forests and Grasslands. Some species flourish there. Other species with more restricted habitat requirements and a lower tolerance for habitat disturbance (about half of the listed and candidate threatened and endangered aquatic species) depend on the National Forests and Grasslands–their primary habitat–for survival.

A Unique Partnership and Mission. Forest Service fish habitat scientists and aquatic ecologists, unique in their focus on the interrelationships among aquatic species and their habitats and their partnership with National Forest and Grassland fish habitat managers, search for the answers resource managers need:

- Understanding of aquatic ecosystem structure and function
- Understanding the effects of land-use practices on aquatic ecosystems and the species that live there
- Developing technology for protecting, restoring, enhancing, and evaluating rivers, streams, lakes, and estuaries and transferring that technology to managers

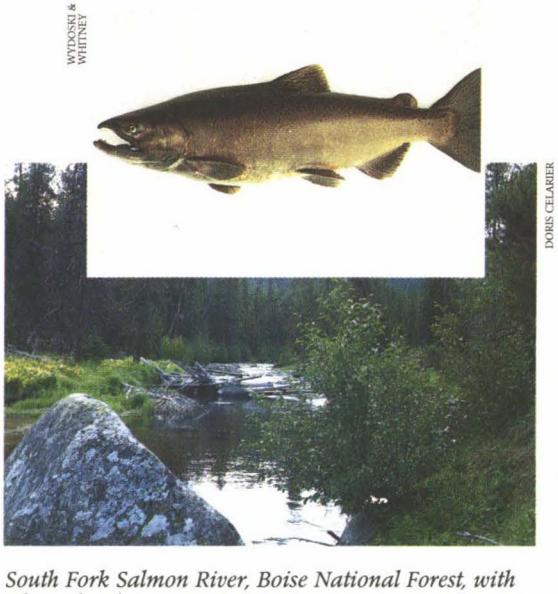
The 156 National Forests and Grasslands

- 191 million acres
- 2 million-plus acres of ponds, lakes, and reservoirs
- 16,500 miles of coast and shoreline
- 200,000-plus miles of perennial streams

MICHAEL YOUNG

MICHAEL YOUNG

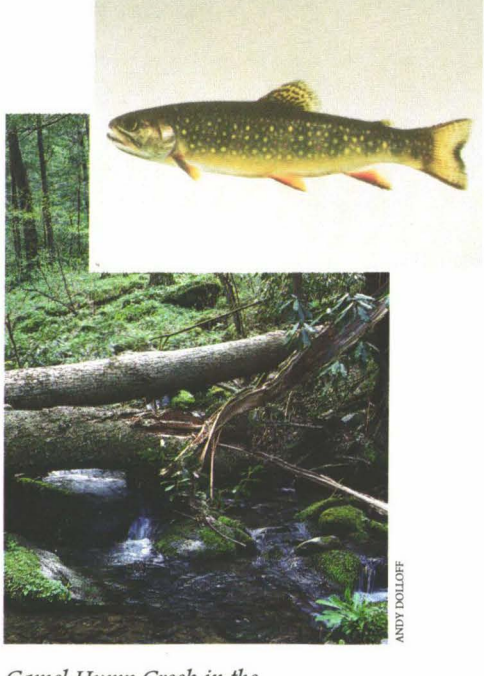
North Fork Little Snake River, Medicine Bow National Forest, with Colorado River cutthroat trout in spawning colors.



WYDOSKI & WHITNEY

DORIS CELARIER

South Fork Salmon River, Boise National Forest, with Chinook salmon.



JOHN SCAROLA

ANDY DOLLOFF

Camel Hump Creek in the Appalachians with brook trout.

The Forest Service Commitment: Ecosystem Management

The Legacy. The Forest Service commitment to managing the National Forests and Grasslands for diverse and productive ecosystems runs broad and deep. This commitment extends from the first days of Forest Service management of the forest reserves to its renewed emphasis on ecosystem management and development of partnership programs, such as Rise to the Future, that give substance to managing for biodiversity and the long term.

Rise to the Future. Rise to the Future, a fisheries management program started in 1987, increased emphasis on fisheries management within the Forest Service by improving the quality of fish habitats and increasing recreational opportunites through the use of partnerships. The user demand and resource need that sparked the program continues to grow. Rise to the Future is an umbrella program incorporating two important initiatives:

Bring Back the Natives–New in 1992, "Bring Back the Natives," a national partnership program of the Forest Service, Bureau of Land Management, and National Fish and Wildlife Foundation, aims, through national, State, and local partners and volunteers, to restore the health of riverine systems and their native species.

National Recreational Fisheries Policy–In 1989 and 1990, respectively, the Forest Service and Bureau of Land Management (BLM), in signing the National Recreational Fisheries Policy, agreed to work together to develop and implement partnerships with constituency groups, individual anglers, the recreational fishing industry, and others to improve the quantity and quality of fisheries through good stewardship and opportunities to fish. The policy, which recognizes agency stewardship responsibilities and increased recreational opportunity, will be carried out through established programs and processes such as the Forest Service's Rise to the Future and BLM's Fish and Wildlife 2000.

Ecosystem Management–the Tradition and the Mandate

- Gifford Pinchot, in the 1905 regulations and instructions he drafted and Secretary of Agriculture James Wilson approved, cautioned: "The permanence of the resources of the reserves is . . . indispensable to continued prosperity."
- In 1960, the Multiple-Use Sustained Yield Act, reaffirming Pinchot's bench mark, called for "harmonious and coordinated management of the resources, each with the other, without impairment of the productivity of the land."
- The National Environmental Policy Act of 1969 declares that encouraging "productive and enjoyable harmony between man and his environment" is national policy.
- The National Forest Management Act of 1976 defines the Forest Service as a leader in "natural resource conservation," to meet the needs of people "in perpetuity."
- In 1992, the Forest Service vigorously renewed its commitment to managing for "diverse, healthy, productive, and sustainable ecosystems," or ecosystem management.

WILLIAM ROSTON

BARRY NEHR

Drainage on the Ouachita National Forest. The Southern Forest Research Station cooperates with the Ouachita, a pilot forest for ecosystem management, in Phase III of the Ecosystem Research Project, paired watershed and fisheries studies. The orangebelly darter lives in most drainages on the Ouachita National Forest.

The Research Contribution to the Scientific Community and First-Class Care

Seeing Early, Seeing Clearly. Through their work, Forest Service fisheries scientists and aquatic ecologists forged a new view of fish habitat management. Their work identified and explained many of the complex interactions among fish and habitats and shed misconceptions hampering management practices. It gave landowners and Forest Service managers a new vision of what high-quality habitat is and how land use affects that quality:

- Large woody debris in streams, thought at one time to be undesirable and cleared out of streams, increases habitat quality for species such coho salmon and Dolly Varden, cutthroat, Apache, brown, rainbow, steelhead, and bull trout at various life stages.
- The riparian area, so attractive to livestock and other users, strongly affects the fish population of a stream.
- How the pristine stream interacted with forests–the historical description of the habitat gleaned from careful review of early records, such as news and file reports and industry records, and analysis of geologic structures and vegetative matters–gives managers a tool to set realistic recovery targets for an area and interpret the long-term effects of land use.
- The status, distribution, and habitat needs of fish species such as native southwestern fish inform the manager what subtle habitat changes and the introduction of nonnative species mean to species viability.
- Anadromous species, introduced to previously inaccessible waters when fish passage facilities open, may affect the viability of resident fish populations.
- Cover and energy affect habitat productivity differently in old- and new-growth forests.
- Mt. St. Helens volcanic eruption changed aquatic habitat and fish population in the blast zone.

. . . about the pioneer Forest Service research fisheries biologists

"They created the textbook standards in fisheries biology. You cannot read a reference handbook or manual in this field without realizing their contribution to the theoretical framework and standard methods we all apply in the course of our research."
–Second-generation fisheries biologist

Debris Volume Estimates

Large Debris (>10 cm)

$$V = \frac{(\pi\ (d_1^2 + d_2^2) \cdot L)}{8}$$

ANDY DOLLOFF

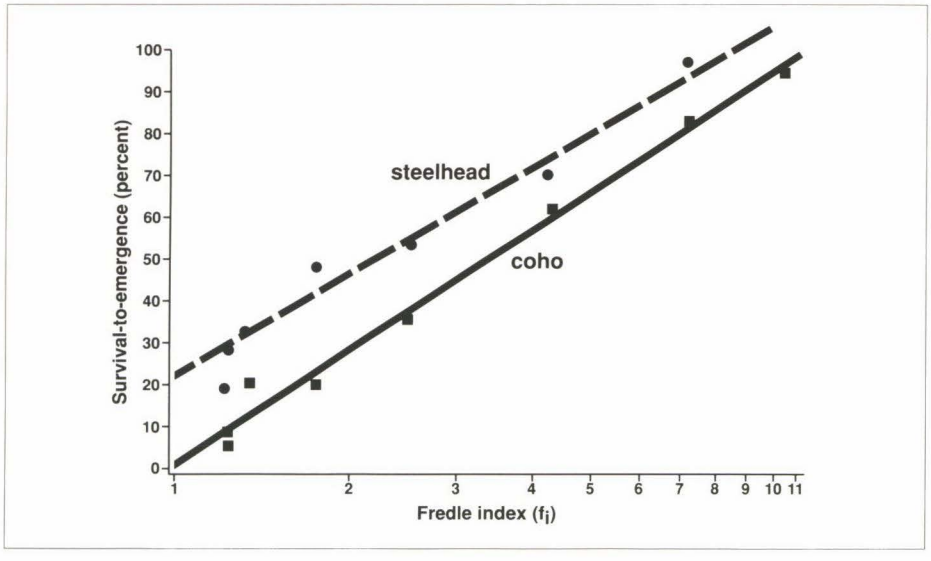
Large Woody Debris. *Large woody debris, such as the pieces added in Big Stony Creek of the Jefferson National Forest, creates fish habitat and contributes to habitat stability. This site, which Southeastern Research Station scientists and graduate students survey here to collect stream channel data, is a reference for comparison with an untouched "control zone." The large woody debris formula developed by Forest Service fisheries scientists is a standard tool for determining volume of large woody debris.*

Applying Scientific Understanding: Techniques, Guidelines, Rating Systems for Researchers and Managers. How does a manager know with some certainty what is the best action to take to protect a resource? What will the effects of that action be? When is the best time to take that action? What are the alternatives? Forest Service fisheries scientists and aquatic biologists have developed techniques, guidelines, and systems to help managers in their decisionmaking and management activities:

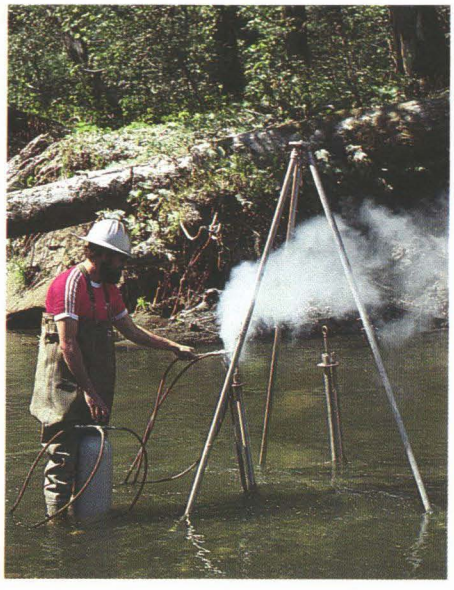
- Statistically valid inventory and monitoring techniques for assessing fish populations and habitats on a basinwide scale.
- Cost-effective procedures for identifying how factors such as woody debris, stream substrate, food, and temperature limit production of salmon and steelhead trout.
- A rating system for use in planning roads and timber harvests to assess the risk of landslides to salmon and steelhead spawning and rearing habitat.
- Guidelines for adding woody debris, boulders, and other structures to streams to restore salmonid habitat diversity and support recovery of threatened and endangered salmon and steelhead.
- Methods and techniques for monitoring and assessing changes in fish habitat caused by land use and assessing the effects of change on community structure of juvenile salmon and sea-run trout.
- Methods for habitat evaluation and protection for small streams.
- A sampler and a statistical index used by investigators in the United States, Canada, and the United Kingdom to assess the composition and quality of streambed gravels for salmonids.
- A portable, inexpensive method for freeze-branding juvenile fish to aid scientists in studying fish movements and production.
- A nonlethal technique using a self-filling syringe to examine stomach contents and study food habits.
- An intragravel flowmeter to conduct rapid assessments of conditions for incubation of salmonid eggs and embryos.

Methods For Evaluating Stream, Riparian, and Biotic Conditions
Methods for Evaluating Riparian Habitats With Applications to Management
INFLUENCES OF FOREST AND RANGELAND MANAGEMENT
ON SALMONID FISHES AND THEIR HABITATS
WILLIAM R. MEEHAN EDITOR
KARL PERRY

Management Guidelines. *These guidelines transferring fisheries scientists' findings to managers are three of the most widely used. The recently published "Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats," edited by Pacific Northwest Research Station research fisheries biologist William R. Meehan, summarizes the latest information on the effects of land uses on fish habitat, the response of fish populations to habitat change, and planning strategies to integrate fish habitats into natural resource management. This seminal book reflects Dr. Meehan's life-long career in scientific inquiry devoted to fisheries and conservation in the Pacific Northwest and Alaska.*



"Fredle Index." *"Fredle index" numbers are indicators of sediment permeability and pore size, determiners of the quality of gravel used for reproduction by anadromous salmonids. This diagram shows the relationship between the fredle index numbers and survival-to-emergence of coho salmon and steelhead trout. Pacific Northwest Station researcher Fred Everest, who developed this important index (along with Fredrick Lotspeich) and other methods to assess and interpret the effects of fine sediments on salmonid habitat, has long studied how land-use activities affect habitat of anadromous salmonids and initiated long-term programs to develop habitat restoration technology and evaluate its effectiveness.*


FRED EVEREST

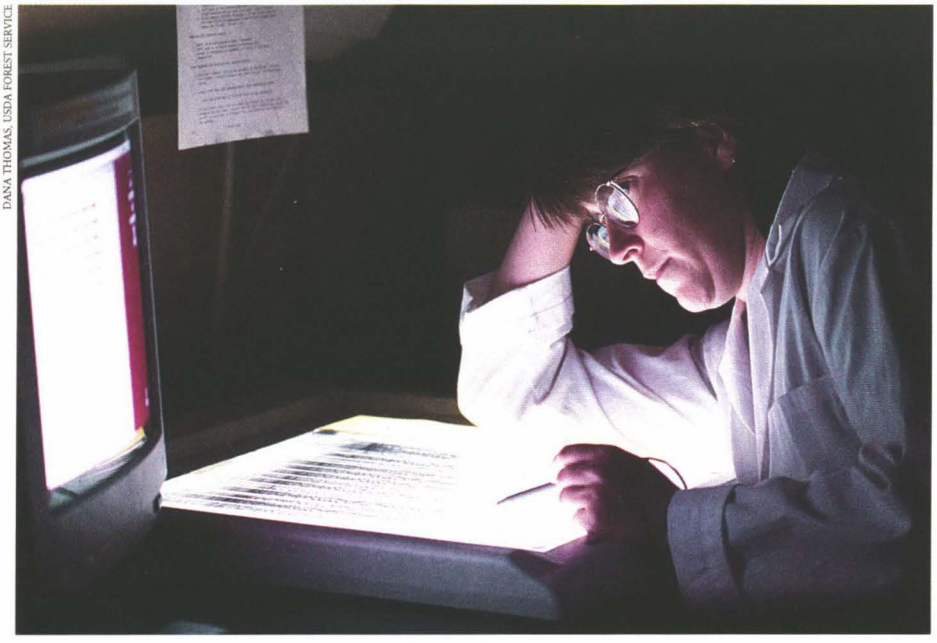
Intragravel Flowmeter. *The intragravel flowmeter measures the rate and direction of waterflow through spawning gravel. Intragravel waterflow and the dissolved oxygen content of the water influence the survival of incubating embryos and the quality of the fry that develop.*

Extending the Benefits. Managers and scientific researchers worldwide accept the results of Forest Service fisheries scientists' work, use the equipment and techniques they have developed, and invite them to participate in information exchange and consultation. Over the past decade, Forest Service scientists have contributed over 300 publications to the scientific literature.

The Million-Billion Dollar Factor: Productive Fisheries and Fish Habitat

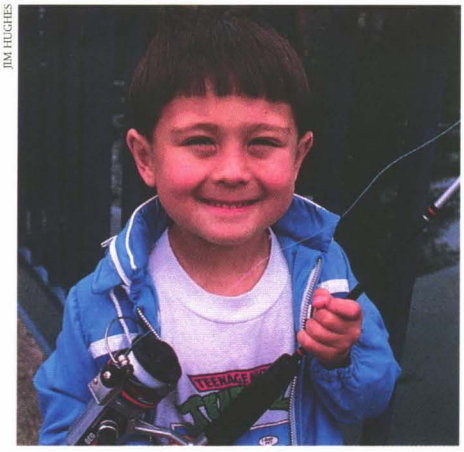
- $7 million–subsistence fishing
- $2 billion–recreational angling
- $255 million–commercial fishing

DANA THOMAS, USDA FOREST SERVICE

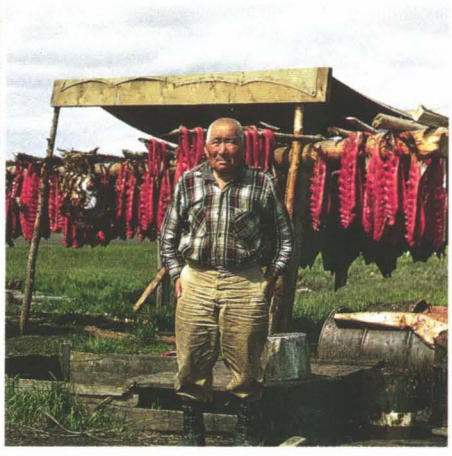


Genetics. *Understanding genetic variability, determining the genetic structure of fish populations, and finding the effects of microhabitat quality on genetic variation are critical to Forest Service efforts to protect and restore populations of species at risk. Pacific Southwest Research Station biological technician Theo Light digitizes DNA autoradiograph onto the computer for analysis.*

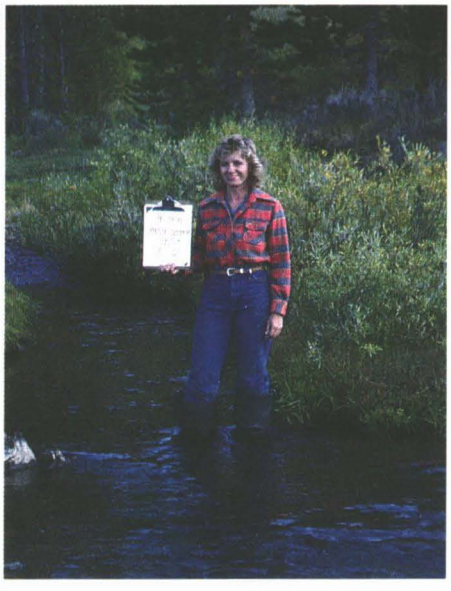
JIM HUGHES



FOREST SCIENCES LABORATORY, JUNEAU, AL



KERRY OVERTON



Technology Transfer. *Technology transfer specialist Kerry Overton of the Enhancing Fish Habitats Research Work Unit (Boise, ID), Intermountain Research Station, advises and teaches managers (such as Jane Schmidt, a Toiyabe National Forest resource officer, who here marks a reference stream monitoring site) methods and procedures in monitoring, inventorying, and evaluating fish habitat. His work puts information gained in research into practice in field projects.*

USDA FOREST SERVICE

A Dedicated, Diverse, Talented Group of Researchers

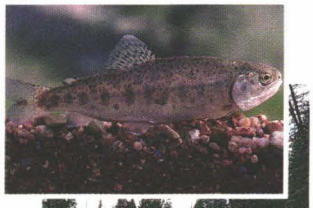
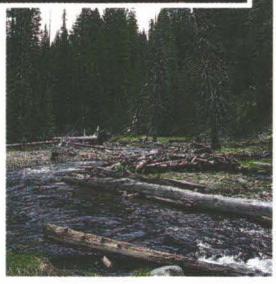
A Small Group, a Big Job. Twenty-six scientists and professional biologists, men and women from many different backgrounds, are stationed in 11 locations in the United States. The roots of the fish community and aquatic ecosystem research in the Forest Service stretch back to 1966, when the first fisheries scientist was hired to work on anadromous fish habitat in southeast Alaska. In the late 1960's and the 1970's, four more scientists joined the staff. In the 1980's and in the current decade, managers' information needs skyrocketed; and even though more researchers joined the team, today's staff copes with an onslaught of serious questions from managers.

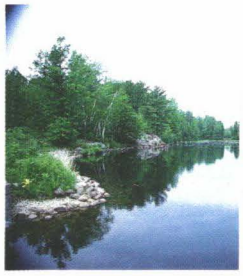
"We Can't Go It Alone." The task ahead for Forest Service fish community and aquatic ecosystem scientists is daunting. "We do not have the resources to search for the answers we need by ourselves," they report. Cooperating with other researchers outside the agency in interdisciplinary research projects is fast becoming the standard way of doing business.

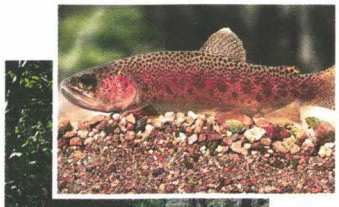
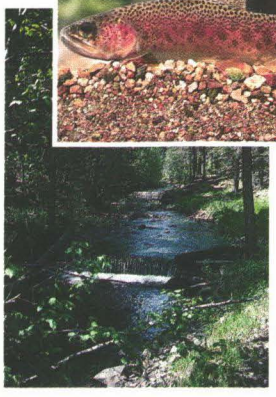
Cooperators: Research Bench Mates and Investors

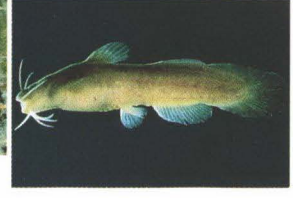
- 13 Federal agencies
- 30 State and local governments
- 56 regions and national forests
- 29 universities
- 2 tribes
- 5 private companies
- 10 associations, societies, and institutes

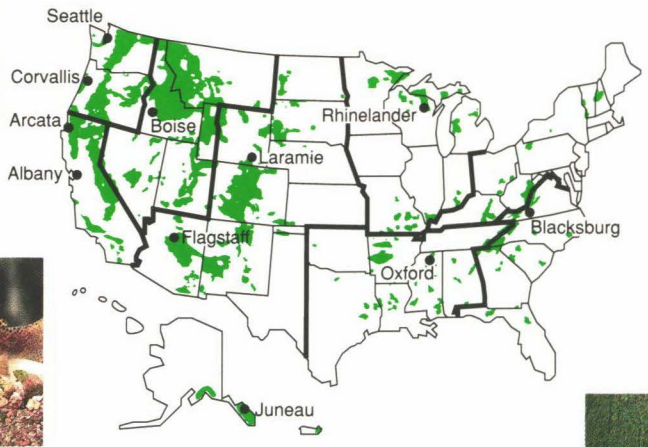
Fish Habitat and Aquatic Ecosystem Research







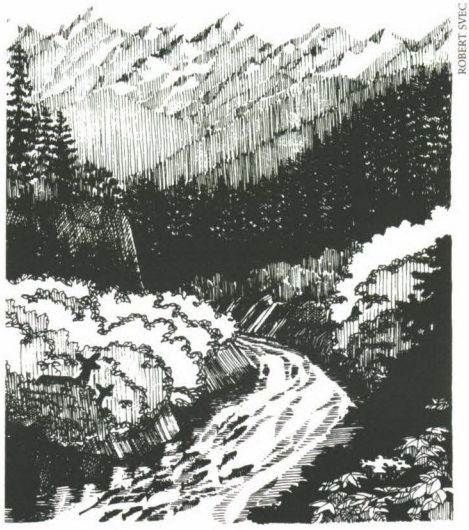
A Closer Look at a Few of the Projects

Interdisciplinary Research on Riparian Ecosystems–Sensitive Ecosystems of High Value for the Nation and the World. Understanding the complex interactions between land and water systems is basic to developing sound guidelines for riparian forest management. In southeastern Alaska, an area with pristine and managed watersheds of high economic, biological, and social value, ranging from alpine headwaters to salt water estuaries, researchers have just launched a 10-year, interdisciplinary research program, part of the Pacific Northwest's Aquatic/Land Interactions Research Program, focusing on major ecological processes controlling riparian ecosystem function, productivity, and response to disturbance. Under Fred H. Everest, program manager, nine Forest Service scientists and various State, Federal, and university cooperators collaborate closely on this program, selected as a participant in the United Nations Education, Scientific, and Cultural Organization's Man and the Biosphere Program on Ecotones.

Restoring Pacific Salmon Populations–Tools To Help Managers Find Best Strategy. Intermountain Research Station (Boise, ID) research fisheries biologist Danny Lee and Resources for the Future fellow Jeffrey Hyman, in a cooperatively funded project, developed the Stochastic Life-Cycle Model, a model that simulates the life cycle of anadromous salmonids. This model, using inputs from more detailed models for specific life stages such as juvenile passage or harvest to express what is likely to happen at each stage, helps managers anticipate the impact of future management action and identify cost-effective strategies.

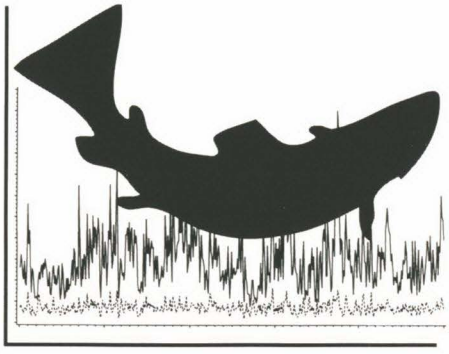
The Aquatic Ecosystem Means More Than Fish. Many freshwater mussel species are declining precipitously–some before basic survey information on them or the ecosystems where they live has been collected. Underway now is a comprehensive review of the current status of native freshwater mussels led by Southern Research Station research fisheries biologist Mel Warren. The survey will collect information on the distribution of the 297 native freshwater mussels in the United States and Canada and then assign conservation status. The review results will determine a much-needed starting point from which to set forth conservation and recovery priorities for one of the richest components of our aquatic ecosystems.

Molecular Genetics and Salmonid DNA. Pacific Southwest Research Station researcher Jennifer Nielsen, analyzing DNA of wild and hatchery salmon from California and other Western United States stocks, identified these wild stocks of fish: A unique stock of steelhead in southern California and, of particular importance to Forest Service managers, relic stocks in the headwaters of the St. Inez River on the Los Padres National Forest. These genetic studies were cooperatively supported, as were other studies on differences in mtDNA in hatchery and wild salmonid populations, mtDNA type of steelhead and the occurrence of bacterial kidney disease in wild populations, and links between environmental factors of freshwater habitats to changes in life history patterns.

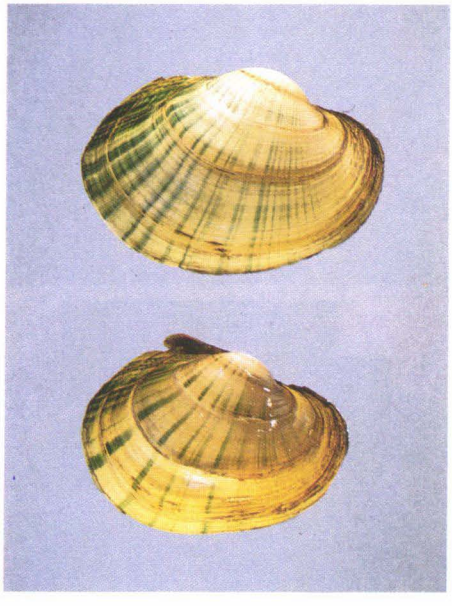


ROBERT SVEC

Riparian area in Alaska.

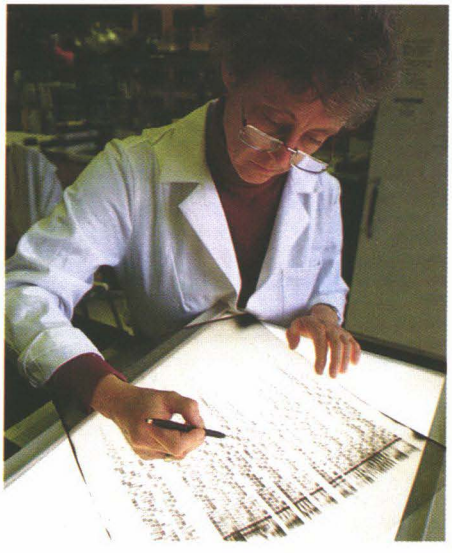


Graphic using model data.



KEVIN CUMMINGS

Plain pocketbook.



DANA THOMAS, USDA FOREST SERVICE

Researcher Jennifer Nielsen reading DNA autoradiograph.

That Beaver and its Dam–Essential or Nuisance? "What are the complex effects of the beaver and its dams on the riparian systems of northern Wisconsin?" ask wildlife managers as they make difficult decisions in resource management. In response, research fisheries biologist Clayton Edwards and other researchers at the North Central Research Station (Rhinelander, WI) are examining–

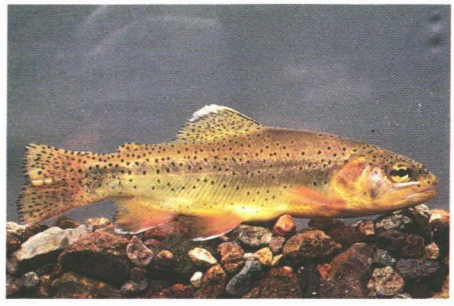
- The relationship of beaver abundance and distribution to tree distribution and succession
- The effect of beaver dams–before and after removal–on stream water temperature
- The importance of beaver dams to brook trout movement and otter predation on brook trout
- The effect of beaver ponds on waterfowl reproduction and food supply

TONY RINALDI

Beaver dam, Scott Creek, Nicolet National Forest, Wisconsin.

Sonoran Desert Region Native Fish–a Photographic Record. Photographs of the 41 species of fish native to the Sonoran Desert region in the Southwest, taken by Rocky Mountain Research Station research fisheries biologist John Rinne, were published for the first time in 1991 through the cooperation of the Rocky Mountain Research Station and Arizona State University. Most of these species are either listed or about to be listed as threatened, endangered, or sensitive. Fish habitat research in the Southwest concentrates on threatened, endangered, and sensitive species, particularly the Little Colorado spinedace and Apache trout, two threatened species persisting principally in the headwater stream environments where drought, wildfire, grazing, and timber harvesting place pressure on their habitat.

JOHN RINNE



Gila trout.

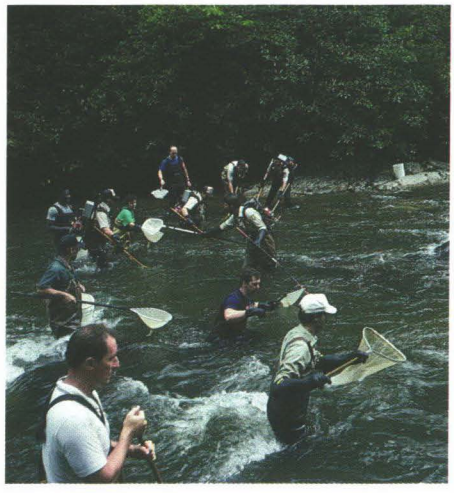
Wild Brown Trout, Native Colorado River Cutthroat Trout. To understand microhabitat use and determine the distribution, movement, and status of wild brown trout and native Colorado River cutthroat trout in southcentral Wyoming, Rocky Mountain Research Station research fisheries biologist Michael Young tracks trout from April to December through radiotelemetry.

MICHAEL YOUNG

Researcher Michael Young and biological technician Keith Kimbrell surgically implant a transmitter in a brown trout.

Land Use and Fish Production in Southern Appalachian Watersheds. Southeastern Forest Experiment Station researchers Andy Dolloff and Patricia Flebbe use visual estimation techniques developed by Forest Service researchers and cooperators to see how land use affects habitat and production of native species such as brook trout and blacknose dace in southern Appalachian watersheds. Through repeated sampling of watersheds (pristine wilderness to traditional multiple-use sites) the researchers can account for natural variation in fish populations and isolate specific impacts such as loading of large woody debris, sedimentation, and angler exploitation.

ANDY DOLLOFF



Crew on fall count of fish populations in Chatooga River.

For Salmon and Trout: Research of the Highest Priority. Using a tri-tube "freeze core" technique, research fisheries biologist Russ Thurow and research hydrologist Jack King extract samples of gravels within redds (where eggs develop into fish) to collect data for entry in the Salmonid Spawning Analysis computer model, a model cooperatively developed by Intermountain Station and Agricultural Research Service scientists. The model, which is linked to other agencies' computer models, gives a more complete understanding of environmental factors in the redds such as the relationship of sediment to embryo survival and how best to preserve critical habitat for sockeye, chinook, and other endangered salmonids.

CAROL JOHNSTON

The Yazoo darter.

RUSS THUROW

Researcher Russ Thurow with sample.

Study the Yazoo Darter (a Species Endemic to Mississippi Headwaters)?–Gain a Model of Headwater Species. In the Yazoo River Drainage in Mississippi, Southern Research Station researcher Carol Johnston studies the life history of the Yazoo darter, a species endemic to the drainage, whose range is mostly in Holly Springs National Forest. From the information she is gathering on reproductive biology and habitat requirements of the Yazoo darter and on its current status, managers will know more precisely how to protect this species and other headwater species in the South.

Radiotracking Trout in a Deep Pool in the California Sierra Nevada. Do trout prefer the cooler portions of a deep bedrock pool? How widespread are thermally stratified pools in the Sierra Nevada? Do similar pools exist in areas that are logged or grazed? These are the questions that Pacific Southwest Research Station researcher Kathleen Matthews and cooperators in a study on a relatively pristine section of the North Fork of the American River are seeking answers to by equipping trout with temperature-sensitive radio transmitters and documenting their movement.

DANA THOMAS, USDA FOREST SERVICE

Researcher Kathleen Matthews electrofishing in the Sierra Nevada, Tahoe National Forest.

Reality Check on Fish Communities and Aquatic Ecosystems

Inventories and assessments clearly report habitat alteration and damage, loss of species, and fish stocks at risk:

- Only 2 percent of all the rivers in the lower 48 States remain at "high natural quality" (1982 Nationwide Rivers Inventory).
- Native fish such as the Gila, Apache, Lahontan cutthroat, and greenback cutthroat trout and other aquatic species such as mussels, snails and aquatic insects–sensitive indicators of water quality–are in decline.
- During the past 100 years, 3 genera, 27 species, and 13 subspecies of fish from North America have become extinct, primarily through habitat alteration (73 percent) (1989 assessment published by the American Fisheries Society).
- In 1989, 364 stocks of inland fish were listed at risk, a 45-percent increase in the 10-year period, 1979 to 1989 (1989 assessment published by the American Fisheries Society).
- Of the more than 400 stocks of the native, naturally spawning stocks of Pacific salmon, steelhead, and sea-run cutthroat trout stocks, 214 stocks were at risk, and over 100, already extinct (1991 assessment published by the American Fisheries Society).
- Habitats in many watersheds on National Forests and other lands in Alaska, California, Idaho, Oregon, and Washington have 30- to 70-percent fewer large, deep pools, more fine sediments in spawning gravels, and greater disturbance of riparian vegetation than is acceptable (USDA Forest Service and DOI Bureau of Land Management PACFISH groups).

Pressing Information Needs Remain: Current and Future Research

Emphasis Areas. Much has been accomplished in the emphasis areas of Forest Service fish community and aquatic ecosystem research:

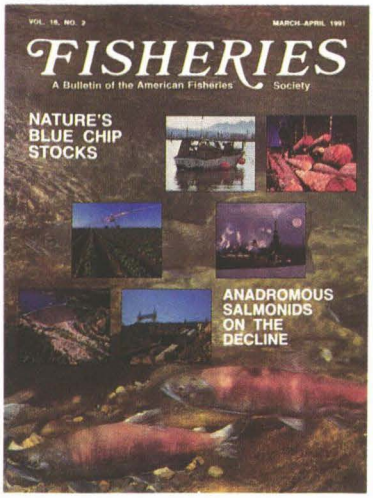
- Inventory, monitoring, classification, and evaluation of fish habitats
- Protection, restoration, and improvement of fish habitats
- Recovery of threatened, endangered, and sensitive species
- Evaluation of user needs and values and benefits associated with fisheries resources

The Research Focus: Managers' Questions. What are some of the questions managers are now asking? Forest Service Research is working on some of them:

- What are the cumulative effects of water development, timber harvest, grazing, mining, and other land uses on fish communities in different geologic provinces?
- How can technologies such as geographic information systems (GIS), global positioning systems (GPS), and remote sensing be used for landscape-scale fish habitat inventory and analysis?
- What components of the life history, behavior, and habitat of sensitive fish are unknown or poorly known and must be understood to protect or recover their populations?
- How does genetic variation in fragmented populations of threatened, endangered, and sensitive fish affect population viability?
- Does fisheries management (for example, stocking) adversely affect the genetic biodiversity of wild fish populations on the National Forests?
- Has habitat rehabilitation helped enhance the recovery of wild stocks?
- How do beaver and otter influence fish production and biodiversity in forest streams and riparian zones?
- How does acid precipitation influence fish distribution, abundance, and community composition in acid-sensitive streams and lakes?
- How does vegetative succession in uplands and riparian zones affect the size, structure, and distribution of fish populations?

"Whether we are referring to the bass fisheries in Florida, the walleye fisheries in the Great Lakes States, or the trout and salmon fisheries in the Pacific Northwest and Alaska, the National Forests and Grasslands support world-class fisheries."

–F. Dale Robertson
Forest Service Chief



KARL PERRY

American Fisheries Society cover for Fisheries, *March-April 1991, featuring assessment titled "Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington."*

Finding Out About the Fish Community and Aquatic Ecosystem Research Program

To obtain information on fish communities and aquatic ecosystem research or find out more about research needs and projects, call or write the research locations listed here:

Intermountain Forest and Range
Experiment Station
Forestry Sciences Laboratory
316 East Myrtle Street
Boise, ID 83702
208–364–4340

North Central Forest Experiment
Station
Forestry Sciences Laboratory
5985 Highway K
PO Box 898
Rhinelander, WI 54501
715–362–7474

Pacific Northwest Forest and Range
Experiment Station
Forestry Sciences Laboratory
3200 Southwest Jefferson Way
Corvallis, OR
503–750–7315

Forestry Sciences Laboratory
2770 Sherwood Land, Suite 2A
Juneau, AK 99801
907–586–8811

Pacific Southwest Forest and Range
Experiment Station
800 Buchanan Street
West Annex Building
Albany, CA 94710
PO Box 245
Berkeley, CA 94701
510–559–6451

Redwood Sciences Laboratory
1700 Bayview Drive
Arcata, CA 95521
707–822–3691

Rocky Mountain Forest and Range
Experiment Station
Forestry Sciences Laboratory
222 South 22nd Street
Laramie, WY
307–742–6621

The Southwest Forest Science
Complex
2500 South Pineknoll Drive
Flagstaff, AZ 86001
602–556–2001

Southeastern Forest Experiment Station
Virginia Polytechnic Institute and
State University
Department of Fisheries and
Wildlife Sciences
Blacksburg, VA 24061–0503
703–231–4016

Southern Forest Experiment Station
Forest Hydrology Laboratory
PO Box 947
Front Street
Oxford, MS 38655
601–234–2744

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FRONT COVER PHOTO CREDITS

Background Photo
East Fork White River, Arizona.
– John Rinne

Left Photo
Pacific Southwest (PSW) Research Station biological techincian Christina Gan loads DNA sample onto agarose gel to check amplification.
–Dana Thomas, USDA Forest Service

Upper Middle Photo
Tag for radiotracking implanted behind eye of adult brown trout.–Michael Young

Lower Middle Photo
Pacific Northwest Research Station research fisheries biologist William R. Meehan.–Elaine Loofstra

Upper Right Photo
PSW Research Station biological technician Derick Williams counts invertebrates, under microscope, in stomach contents of fish.–Dana Thomas, USDA Forest Service

Lower Right Photo
PSW Research Station biological technician Theo Light analyzes water quality, using hydrolab monitor from boat.
–Dana Thomas, USDA Forest Service

MAP PHOTO CREDITS – Page 7

Upper Left Photo Pair
North Fork Little Snake River, Medicine Bow National Forest, Wyoming.
–Michael Young

Colorado River cutthroat trout.
–John Rinne

Lower Left Photo Pair
East Fork Little Colorado River, Apache-Sitgreaves National Forest, Arizona.
–John Rinne

Apache trout.–John Rinne

Middle Photo Pair
South Fork of the Salmon River, Boise National Forest, Idaho.–Doris Celarier

Chinook salmon.–Wydoski & Whitney

Upper Right Photo Pair
Butternut Lake, Nicolet National Forest, Wisconsin.–Tony Rinaldi

Walleye Pike.–John Scarola, New Hampshire Fish and Game Department

Middle Right Photo Pair
Camel Hump Creek, Tennessee, Great Smoky Mountain National Park.
–Andy Dolloff

Brook trout.–John Scarola, New Hampshire Fish and Game Department

Lower Right Photo Pair
Alum Creek, Ouachita National Forest, Arkansas.–Ouachita National Forest

Ouachita madtom.–J.R. Shute

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